Final Report

Quantitative Characterization of Machining Marks For Comparative Identification

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Abstract

This project involved examination of surfaces using a combination of optical microscopy coupled with quantitative measurements of the surface relief. The surface was examined optically and regions of interest identified for examination. Replicas were obtained from the surface and they and the original surface were characterized using a two-dimensional profilometer. The data was statistically evaluated to ensure that the replica accurately portrayed the surface. A computer program was written to compare scans from unknown and known samples to identify regions of interest for closer examination.

Project Description

The technique of comparative identification of toolmarks has been used successfully for many years and was sufficient in that it met the standard criteria established over 80 years ago in the case of Frye v U.S. The Daubert case has led to the need for a more rigorous examination based on more scientific methods.

The analysis of tool marks present a special challenge in that the mark left is also a function of how the instrument was used by a particular individual. The force applied, angle of attack. etc. all make a difference in the appearance of the markings. The proposed project sought to extend the quantification of tool marks from a two-dimensional examination to a three-dimensional one. The hypothesis under consideration was thus:

Tool markings (scratches, etc.) are characteristic of a particular tool and can be measured and quantitatively assessed using surface replication methods.

The experimental procedure followed involved the examination of a number of known and unknown samples produced by Jim Kreiser, a retired toolmark examiner for the State of Illinois. various machining methods. The proposed program can be summarized in the following steps:

Task 1. Examine the known samples and select areas for replication.

Task 2. Produce surface replicas of the selected areas for quantitative evaluation.

Task 3. Conduct a survey of the replicated surface using a two-dimensional profilometer to measure the surface roughness of the markings as a function of x-y coordinates.

Task 4. Conduct a statistical analysis of the data collected to determine whether the replica accurately reflects the actual surface of the sample.

Task 5 Compare the analysis of the unknown surface to the known surfaces and determine whether it can identified with a high degree of confidence.

Objectives

The objective of this proposal will be to develop a method to quantitatively measure surface roughness as a means of identifying features such as toolmarks. The method will be applicable to any shaped surface and will involve a statistical analysis of the data to determine the probability of a match between and unknown and a standard sample. The overall goal is to provide local, state, and federal law enforcement officials with statistically valid data that is suitable for courtroom presentation.

Procedures

All samples were produced by Jim Kreiser, retired forensic scientist of the Illinois State Crime Laboratory. A series of screwdrivers were purchased and both sides were used to produce markings on a series of small brass and lead plates. One plate was selected RepliSet, a two-component silicon rubber compound that is commercially available was used to produce replicas of the surface. The surface relief of the replicas and original marks was examined using a Detroit Precision Hommel profilometer. The surface profile was found by moving a delicately balanced diamond stylus across the surface of the toolmark perpendicular to the mark. Height measurements are taken at periodic intervals and the data output of the profilometer is obtained as an array (or matrix). Normally, a three-dimensional image will be produced by making a series of parallel passes across the surface, a typical scan involving up to 6000 lines with 9600 data points being taken along each line. The collected data was analyzed using a computer spreadsheet.

The samples used in this study were also examined by Jim Kreiser with a standard comparative microscope employing a 1x, 1.5 and 2X objectives with 10X oculars. The Numerical Aperture of the 2X objective, which gave the highest magnification and resolution, was 0.25.

Results/ Discussion

Some of the initial results of this project are summarized in the attached manuscript "Examination of Toolmark Replicas Using a Surface Profilometer." This paper basically covers Tasks 1-4 as outlined in the Project Description.

The status of Task 5, comparison of an unknown surface to known surfaces and determine whether it can identified with a high degree of confidence, concerns development of a computer routine. This project is continuing under funding from the NIJ. The present status will be summarized.

The challenge in analyzing the profilometer scans is to determine a method that will correctly mark and identify striations that are of note while disregarding noise. While this is easy in scans such as x-ray diffraction where peaks assume easily modeled gaussian shapes, it is more difficult in a scan where there is no standard peak shape or size. Figure 1 shows the raw data from two typical scans. Note that visually it can be seen that the traces are similar, i.e. the eye can identify several common macroscopic characteristics. However, the overall slope of the scans and the absolute values for heights, valleys and peak widths changes from scan to scan. This presents a significant problem when comparing the scans mathematically. Accordingly a routine was written to determine the average height and, using this, peaks were compared to this value to determine whether they were above or below a threshold value established by the operator. The routine first check to see if the peak was above or below background, then a side-to-side point comparison was made to determine an average height of the peak above or below background. Using this routine, peaks and valleys could be identified and compared from one trace to another. Figure 2 shows the results from two separate marks made using screwdriver #1. Visually the scans are now much more comparable than the raw data.

Once "fitted" scans were obtained the data could then be compared to each other and certain parameters measured to determine the degree of fit. This match routine was tested by comparing scans between known "matched" and "unmatched" areas as identified by Mr. Kreiser. Examples of typical results are shown in Figures 3 and 4. The match routines compares the number of similar peaks above / below background that are within a user defined interval. The average heght of the peak is also compared. Good matches should have a large match value (i.e. number of peaks matching) and relatively high width and height match values. For example, in the case of the match shown in Figure 3 the match value was 21 with a match width of 0.814 and a match height of 0.846.

Given the manner in which the match routine works it will <u>always</u> find a match. Therefore, the match value, width and height numbers only have significance in a relative sense. An example of a nonmatch is shown in Figure 4. Figure 4a shows the raw data obtained from a mark made using screwdriver #3, side B; the fitted data using the background leveling and peak finder routine developed is shown in Figure 4b. When this scan is compared to the data obtained from screwdriver #1, side A (Figure 4c), a significant difference is observed as compared to the results shown in Figure 3.

A large number of comparisons between known "matched" and "unmatched" samples was conducted. As expected, the quality of the fit varied from sample to sample but a bimodal distribution was apparent between known "matched" and "unmatched" marks. In general known match values were always higher than 8-9 with width and height values near 0.8. Known "unmatched" samples usually had less than 8 matched peaks with slightly poorer width and height values. Although any single "nonmatch" comparison might have a better width and height fit than a known "match" sample, in no cases were all three comparison numbers better for a "nonmatch" than for a "match".

These initial results were used as the basis for a proposal submitted to the National Institute of Justice. Notification of funding has been received and work is continuing to refine this routine. We hope to develop a better matching routine that will use an internal comparison method to give an idea of the quality of the match routine. Work on this project is continuing in conjunction with Max Morris of the statistics department. Initial results will be summarized in a paper to be submitted to the journal of Forensic Science.

Dissemination

As discussed above, the paper "Examination of Toolmark Replicas Using a Surface Profilometer," C. Bossard, L.S. Chumbley, L. Genalo, M. Besser, authors, is in final stages of preparation for submission to the Journal of Forensic Science. An additional paper "Computer Routine for Comparing Profilometer Scans of ToolMarks" is planned.

A talk entitled "Quantification of Toolmarks," authors L.S. Chumbley, C. Bossard, L. Genalo, J. Kreiser, was presented at the annual meeting of AAFS held in Dallas, TX, 2004. A local presentation was given, "Characterization of Tool Marks," at the Midwest Forensics Resource Center in Ames, Iowa, June 5, 2003.

Figures

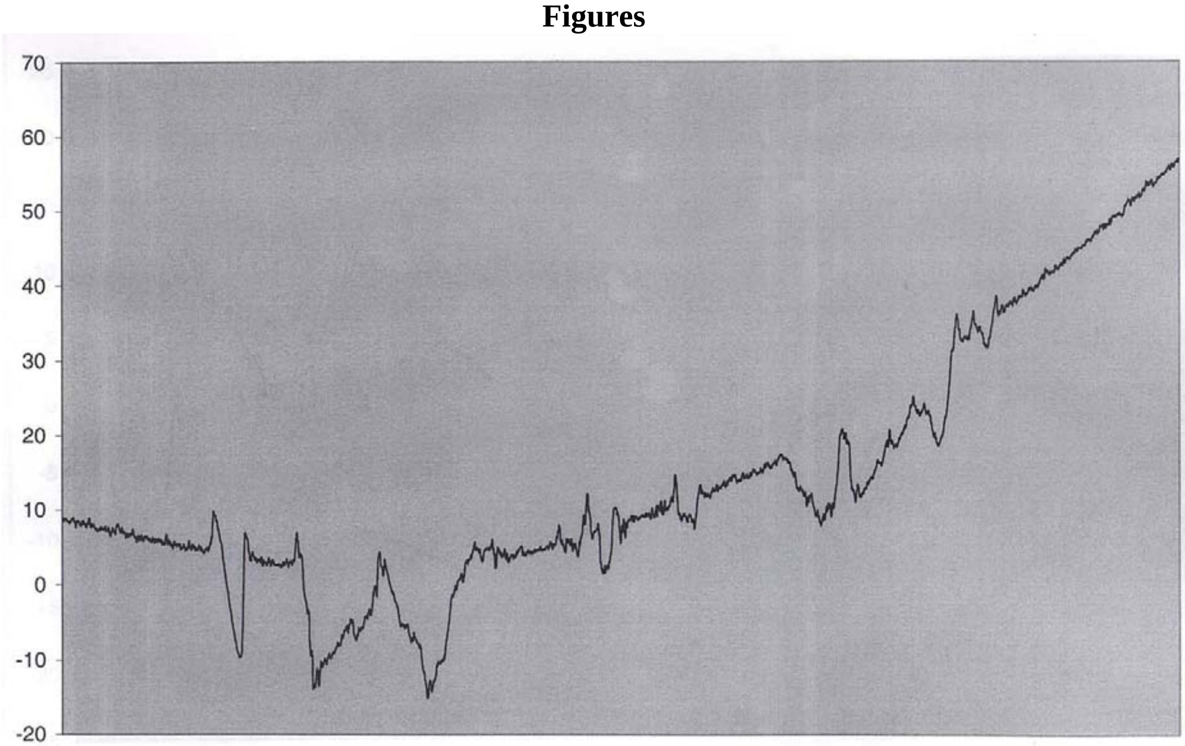

Figure 1a) Typical profilometer profile scan obtained from screwdriver #1, side A.

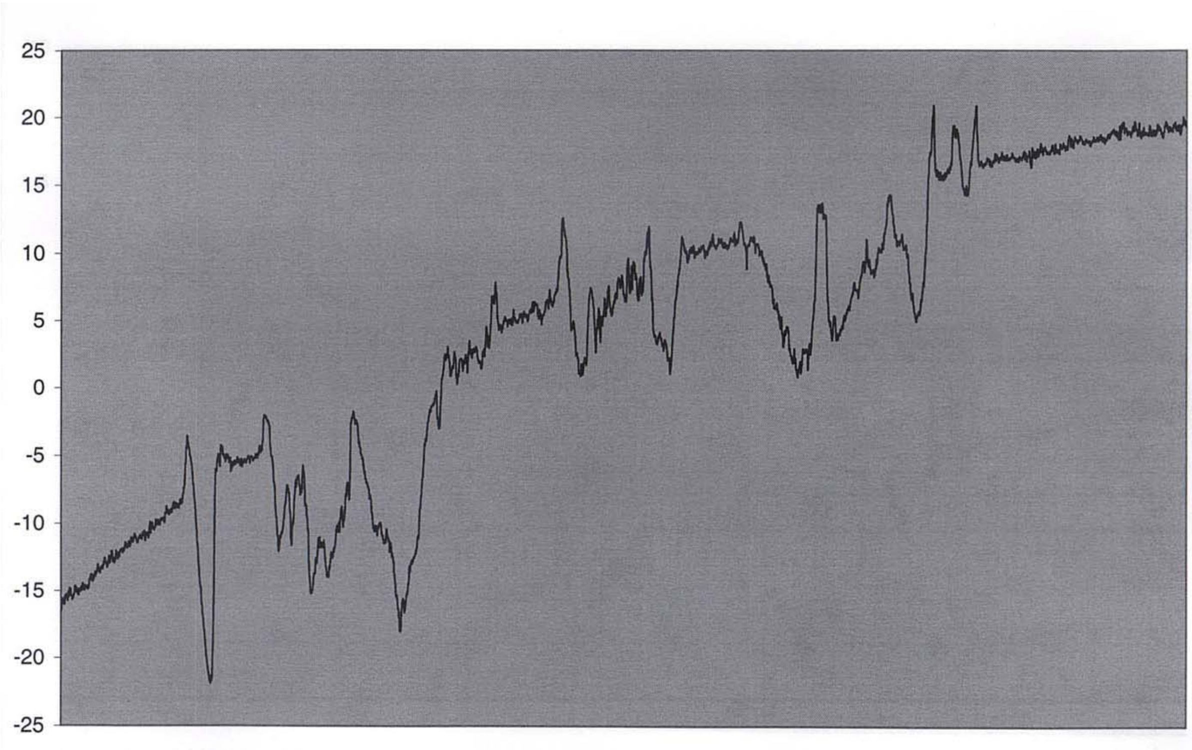

Figure 1b: Raw scan obtained from a second mark made with screwdriver #1, side A.

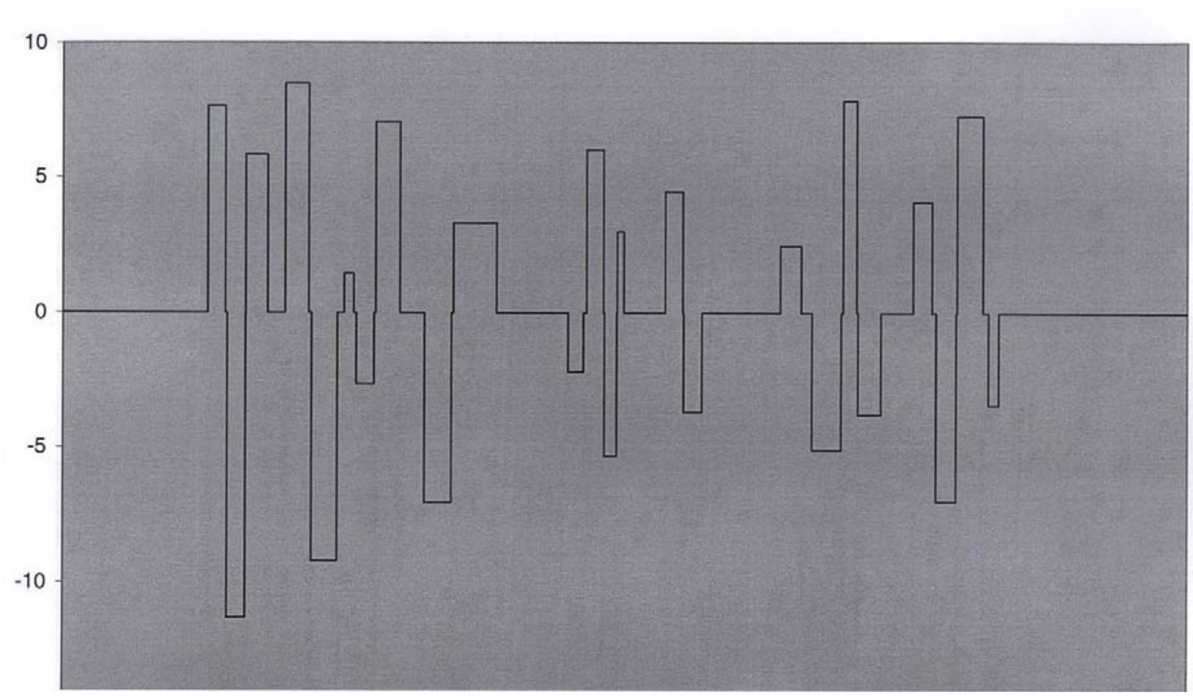

Figure 2a: Processed scan after a background has been fit to the raw data and course peak information extracted. From a mark produced by using screwdriver #1, side A.

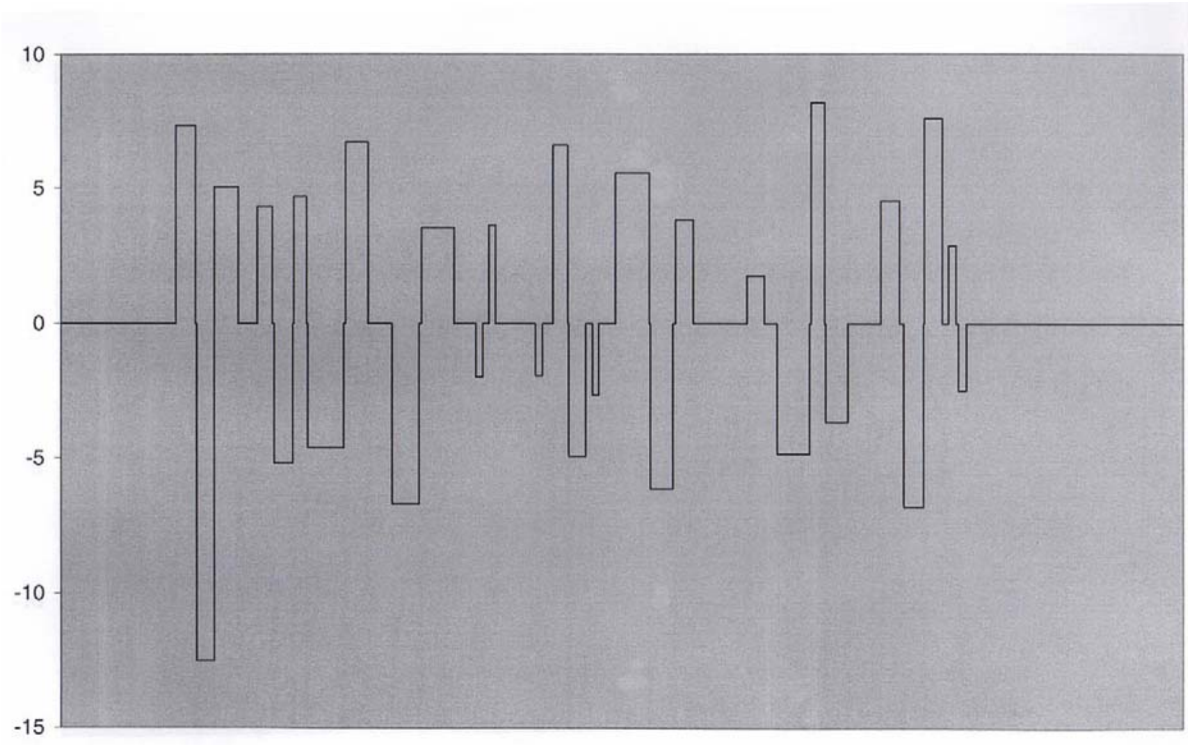

Figure 2b: Processed scan from a second mark produced by using screwdriver #1, side. Note that visually this scan is very similar to the scan shown in a).

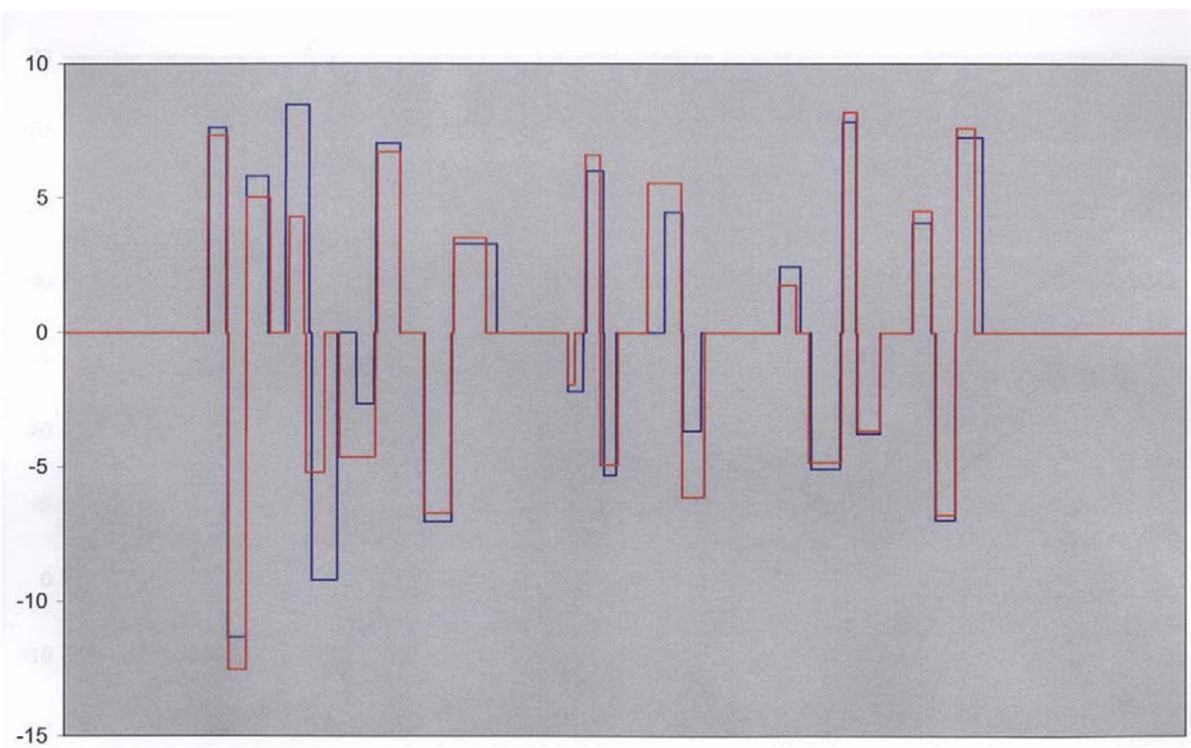

Figure 3: Comparison of two marks made using screwdriver #1, side A.

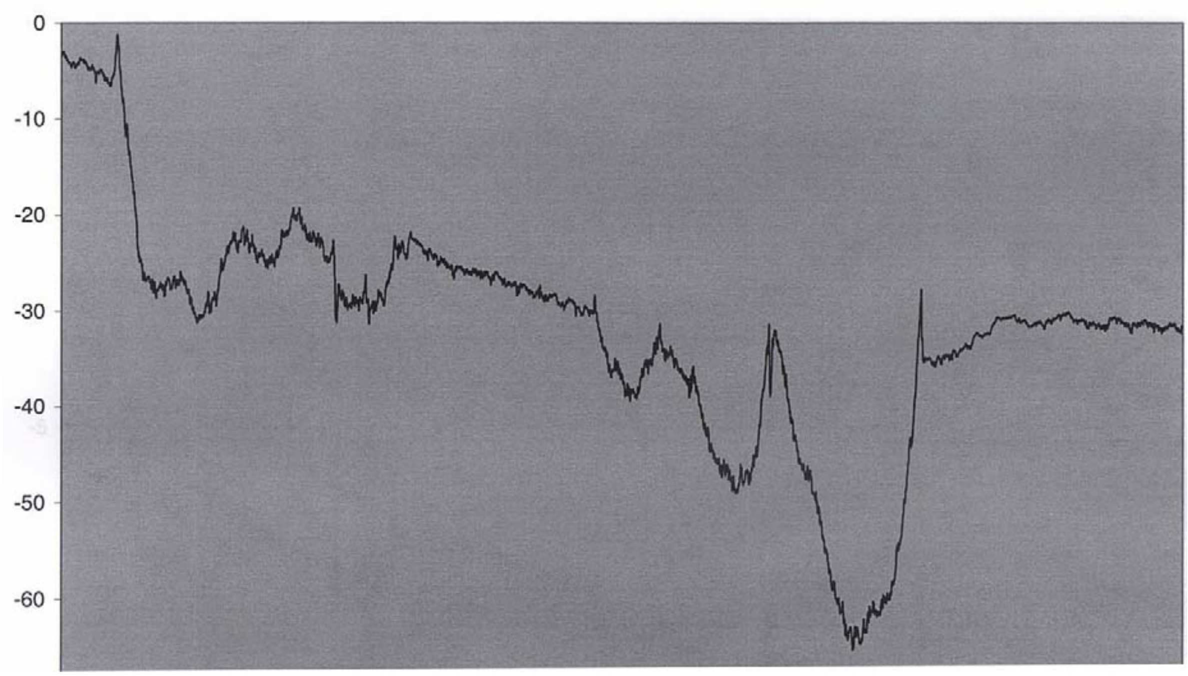

Figure 4a: Raw profilometer data from a mark made by screwdriver #3, side B.

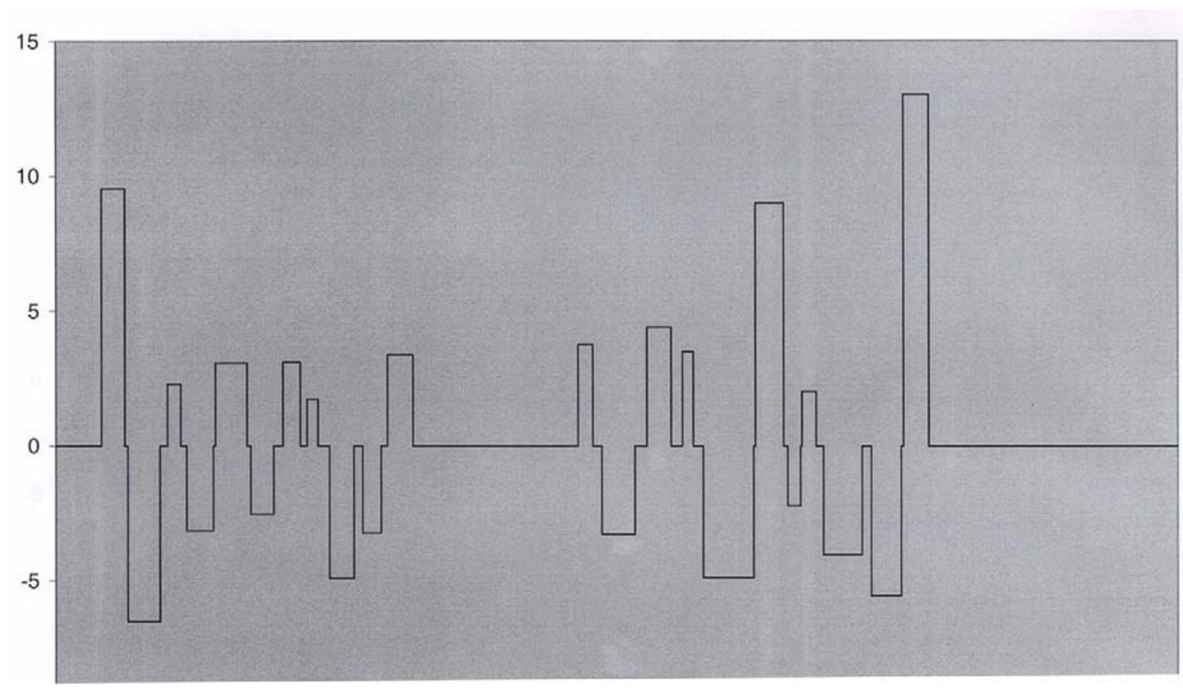

Figure 4b: Fitted data from screwdriver #3, side B.

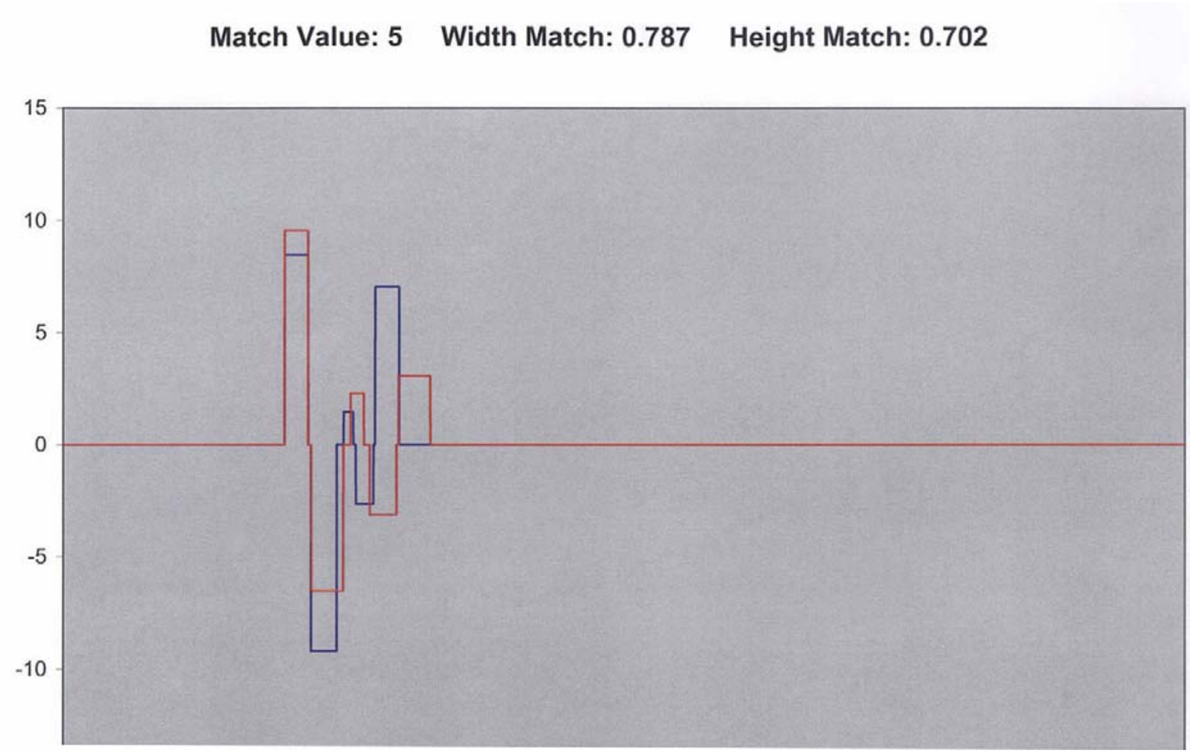

Figure 4c: Comparison of data from a mark made by Screwdriver #1 side A to a mark made by Screwdriver #3, side B. Note the low Match, Width, and Height values as compared to Figure 3.